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Relationship of Mineral Nutrients to Growth of *Spartina alterniflora* in Louisiana Salt Marshes

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Northeast Gulf Science Vol 10, No. 1, December 1988 55

RELATIONSHIP OF MINERAL NUTRIENTS TO GROWTH OF *Spartina alterniflora* IN LOUISIANA SALT MARSHES

Louisiana contains the largest and one of the most productive coastal wetlands in the United States. The marshes exhibit a striking zonation of emergent plants. Vegetation types range from a band of salt marshes parallel to the coastline near the Gulf of Mexico to brackish and then fresh water plants with increasing distance from the Gulf. The predominant vascular plant is *Spartina alterniflora* Loisel which covers 62% of the Louisiana salt marsh (Chabreck 1972). There are several reports of the relationship of mineral nutrient to growth of *S. alterniflora* tissue found in the literature (Williams and Murdock 1969; Broome *et al.* 1975; Gallagher 1975). However, most of the reports are data from Atlantic coast marshes. In the Louisiana gulf coast, most studies in the mineral nutrition of *S. alterniflora* have dealt with responses to added nitrogen and phosphorus (DeLaune *et al.* 1983; Buresh *et al.* 1981) with little or no information on levels of concentration of elements in plant tissue in relation to nutrient status of sediment. The objectives of this study were, therefore, (1) to determine the level and range of nutrient concentrations in salt marsh soil and plant tissue and (2) to evaluate plant productivity and soil-nutrient relationships of *S. alterniflora* along Louisiana's gulf coast.

MATERIALS AND METHODS

Thirty *S. alterniflora* sites over an 8 km distance were sampled along Louisiana's Gulf Coast near Leeville (Figure 1). The site represented various productivity levels and included both

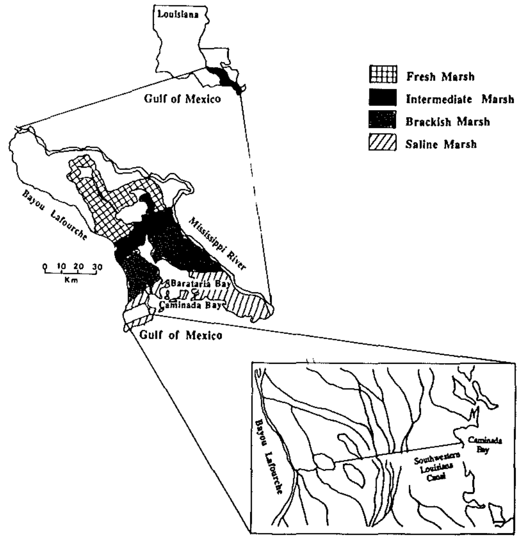

Figure 1. Location of Sampling Sites

streamside and inland locations. Samples were taken on May 20 to coincide with the time of year when the demand for plant nutrients would be a maximum. Biomass was determined from plant material collected from 1.0 m² plots. The plants were clipped at ground level at each location. In addition, at each site, a 10 cm diameter soil core (15 cm in depth) was taken for determining bulk density and nutrient status of the marsh soil. Bulk density was determined from oven dry weight of sediment in core volume.

Measurements of plant height were recorded for five randomly selected stems per each sample plot. Plant samples then were dried at 70°C. to a constant weight and the dry weight was recorded.

Dried samples were divided into subsamples and ground in a Wiley mill for nutrient analysis. Concentrations of N, P, K. Na, Ca, Mg, Fe, Zn, Mn, Cu, and Zn in the plant tissue were determined. Total nitrogen was determined by the kjeldahl method. Total element content of the plant material was determined after digesting in nitric-perchloris-hydrofloric acid. Element content was determined by flameless atomic absorption spectrophotometer equipped with a background corrector. Phosphorus was determined by the molybdate blue method using ascorbic acid.

Soil samples taken from the study sites were subsectioned and air dried, ground and analyzed for total element content using the methods described above for the plant analyses. Percent carbon in soil was determined using dry combustion methods and trapping evolved CO_2. Nutrient levels were expressed on both a weight and volume basis.

Data Analysis

Simple regression analysis and multiple regression of the most important variables were performed using Statistical Analysis System (SAS, SAS Institute, Carry, N.C.). The latter models were constructed to include important variables with regression coeficients significant at the 0.05 level or higher to increase the predictability of the model.

RESULTS

The concentrations of nutrients in plant tissue and soil are presented in Tables I and II, respectively. In addition to the range of concentration for each element, mean and standard deviations are presented. Knowledge of the mean and range of nutrient levels both in sediment and in plant tissue are essential to avoid errors in interpretation of data. Results (Table 1) indicate that K, Ca, Mg, and Mn were at adequate levels to support plant growth while N, P, Fe, Zn, and Cu levels in plant tissue suggest possible deficiency levels.

Regression analysis was performed to determine the correlation among plant nutrient level, plant height and above ground biomass production (Table 3). The correlation matrix of foliage element concentration and the height and biomass production of *S. alterniflora* (Table 3) indicated several significant relationships. The relationships between the tissue concentration of P, K, Na, Mn, and Mg and productivity were significantly correlated. However, productivity was not significantly related to foliage N, Ca, Fe, Cu, and Zn levels. The low correlation coefficient between N, Ca, Fe, Cu, and Zn elements and biomass production suggests that foliage concentration of these elements is among many factors contributing to productivity of *S. alterniflora*.

The correlation matrix of sediment nutrient level (on volume basis ugcm^{-3}) and *S. alterniflora* height and aboveground biomass production (Table 4) indicated similar results as was found for tissue nutrient data presented in Table 3.

Table 1. Range of nutrient concentrations in *S. alterniflora* tissue (μg/g).

Variable	Minimum	Maximum	Mean	Standard Deviation
Nitrogen	7300	21500	10000	2470
Phosphorus	684	1380	1025	181
Potassium	7625	17375	11790	2460
Sodium	31400	61750	48207	7848
Calcium	7750	15000	10578	1567
Iron	67	475	155	77
Manganese	18	99	57	24
Magnesium	1625	3656	2448	445
Copper	3	5	4.4	.94
Zinc	9	20	12.8	2.6

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Table 2. Range of nutrient concentrations and total elements in 30 marsh soil samples.

	Concentration µg/g				Concentration µg/cm³			
Variable	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation
Nitrogen	3300	10000	6300	1830	800	2700	1760	360
Phosphorus	338	768	494	90	77	214	144	37
Potassium	3250	7875	5586	1086	943	2403	16611	385
Sodium	23250	69750	41844	12727	6618	17050	11673	2190
Calcium	50	625	194	140	15	256	56	48
Iron	3750	11350	7716	1758	1050	3600	2266	722
Manganese	50	108	70	12	9	36	20	6
Magnesium	5750	12150	8340	1378	1505	3076	2395	426
Copper	8	20	11	3.1	1.3	5.6	3.2	0.9
Zinc	24	85	52	10.4	7	31	15.8	5.2
Calcium	5.3	12.7	7.6	1.7				

Table 3. Correlation coefficient between element concentration (µg/g) in plant tissue, and plant biomass, and height.

Nutrient	Plant Biomass	Plant Height
Nitrogen	−.074	−.267
Phosphorus	.583**	.588**
Potassium	.785**	.773**
Sodium	.392*	.409*
Calcium	−.163	.024
Iron	.113	−.140
Manganese	.666*	.555**
Magnesium	−.460*	−.306
Copper	.235	.116
Zinc	.362	.475**
Plant Biomass		.812**

* Significant at 5% level
** Significant at 1% level

Table 4. Correlation coefficient between total element (µg/cm³) content in sediment, and plant biomass, and height.

Nutrient	Plant Biomass	Plant Height
Nitrogen	.129	.270
Phosphorus	.707**	.789**
Potassium	.573**	.549**
Sodium	−.082	−.005
Calcium	.125	.009
Iron	.539**	.532**
Manganese	.603**	.512**
Magnesium	.333	.404*
Copper	.363	.361
Zinc	.545**	.523**
Carbon	.043	−.170
Bulk Density	.700**	.644**
Standing Biomass		.812**

* Significant at 5% level
** Significant at 1% level

Again, productivity was not significantly related to N, Ca, Mg, and Cu concentration in the sediment. Nutrient concentration in sediment was expressed on volume basis since this represents the nutrient per volume of marsh soil which would be available to plants especially in soils of low bulk densities. There was a highly significant relationship between plant height and plant biomass (Table 3). A significant relationship was found between bulk density of marsh soil and plant biomass (Table 4). The variation in growth and height among sites was apparently related to the amount of mineral sediment being deposited on the marsh. Mineral sediment being deposited on the marsh surface would be a source of nutrients available to *S. alterniflora*. A significant correlation was also found between plant productivity and the level of P, Mn, Fe, K, and Zn. Another interesting finding is that while Na concentration in the soil had no correlation with biomass production, the Na level in the foliage was significantly correlated with growth. Concentration of many elements in the sediment matched concentrations in foliages. For example, N, P, K, Na, Mn, Cu, and Zn all had comparable levels in both sediment and plant tissue. On the other hand, Mg and Fe levels were much greater in sediment as compared to plant tissue while Ca level was substantially higher in plant tissue than in the sediment. Concentrations of P, K, Mn, Fe, and Zn in both sediment and plant tissue showed positive correlations with productivity.

DISCUSSION

In Louisiana, nitrogen deficiency is reported to be an important factor controlling productivity of *S. alterniflora* (DeLaune *et al.* 1983), however, data presented in this study suggest that nitrogen alone may not account for all variation in *S. atlerniflora's* growth. In this study no relationship between nitrogen concentration of foliage and above ground biomass production was observed. However, nitrogen levels in the soil were low for the entire transect from which the present data was collected. The absence of data from a nitrogen enriched site in our data set may have masked the existing relationship between productivity and plant tissue nitrogen content.

Phosphorus level in plant tissue, however, was highly correlated with productivity which suggests that phosphorus may be limiting at the beginning of the growing season. This is in contrast to phosphorus fertilization studies (Patrick and DeLaune 1976; Buresh *et al* 1981) which reported no increases in plant biomass at the end of the growing season following phosphorus addition. Apparently with the progression of the growing season, there are other factors controlling plant growth which are more limiting than phosphorus.

In the present study, in contrast to low N availability, Mn, and Fe were generally more available under anaerobic soil conditions. Similar findings as shown in this study were reported for Mn and Fe availability by Jones and Etherington (1970). The results indicated that many nutrients which had high concentrations in the soil also had high concentrations in plant tissue. However, there are conflicting reports on the relationships between soil nutrient levels and plant uptake (Tiffin 1972). For example, Dick *et al.* (1985) reported little or no correlation between available micronutrients in the soil and plant uptake. As pointed out by Dick *et al* (1985), foliar analysis is a more reliable guide to nutrient status of the plant compared to soil analysis.

An interesting finding is the significant correlation found between *S. alterniflora's* productivity and tissue Na concentration. If the level of Na in tissue was lower than sediment, then this finding would have provided the evidence of active Na exclusion by *S. alterniflora's* roots. Active Na exclusion by roots has been reported for other species under both aerobic and anaerobic conditions (Drew and Dikumvin 1985). However, Na concentration was at the same level for both sediment and plant tissue suggesting that relatively salt tolerant *S. alterniflora* copes with high salinity conditions by other mechanisms. One such mechanism reported in the literature is salt excretion (Haines and Dunn 1985).

Positive correlation of manganese to plant growth (Table 3 and 4) is in contrast to that reported by Broome *et al.*, 1975 for Atlantic Coast salt marshes. They reported a negative correlation between manganese concentrations in plant tissue and plant yield. There are apparently greater quantities of manganese in soils with higher bulk densities where manganic manganese (under anaerobic conditions) is biologically reduced to the more soluble manganous form. Apparently, there is a greater amount of this reduced form available for plant uptake in soils with greater bulk density where maximum plant growth occurs.

Results presented indicate that tissue concentration of several nutrients and soil properties were significantly associated with variation in yield and height of *S. alterniflora*. In many instances nutrient concentration per unit soil volume was shown to best correlate with plant tissue concentration. It is important to note that the relationship presented may not be a direct cause and effect. However, the relationship provides only an insight into soil properties and nutrient level as related to the growth of *S. alterniflora*. Many additional factors, such as soil sulfide levels (DeLaune *et al.* 1983) and oxygen deficiency in root rhizosphere (Mendelssohn *et al.* 1981) also govern productivity of marsh vegetation.

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